Patent Application for

# DIGITAL INTERFACE IN RADIO-FREQUENCY APPARATUS AND ASSOCIATED METHODS

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## Cross-Reference to Related Applications

This patent application claims priority to Provisional U.S. Patent Application Serial No. 60/261,506, Attorney Docket No. SILA:072PZ1, filed on January 12, 2001. This patent application further claims priority to Provisional U.S. Patent Application Serial No. _____, Attorney Docket No. SILA:072PZ2, titled "Partitioned RF Apparatus with Digital Interface and Associated Methods," filed on March 2, 2001. This patent application incorporates by reference the above provisional patent applications in their entirety.

Furthermore, this patent application relates to concurrently filed, commonly owned U.S. Patent Application Serial No. _____, Attorney Docket No. SILA:072, titled "Partitioned Radio-Frequency Apparatus and Associated Methods."

## Technical Field of the Invention

This invention relates to radio-frequency (RF) receivers and transceivers. More particularly, the invention concerns (i) ways of partitioning high-performance RF receiver or

transceiver circuitry into circuit partitions so as to reduce interference effects among the circuit partitions, and (ii) circuits and protocols that facilitate interfacing among the circuit partitions.

## Background

The proliferation and popularity of mobile radio and telephony applications has led to market demand for communication systems with low cost, low power, and small form-factor radio-frequency (RF) transceivers. As a result, recent research has focused on providing monolithic transceivers using low-cost complementary metal-oxide semiconductor (CMOS) technology. Current research has focused on providing an RF transceiver within a single integrated circuit (IC). For discussions of the research efforts and the issues surrounding the integration of RF transceivers, see Jacques C. Rudell *et al.*, *Recent Developments in High Integration Multi-Standard CMOS Transceivers for Personal Communication Systems*, INVITED PAPER AT THE 1998 INTERNATIONAL SYMPOSIUM ON LOW POWER ELECTRONICS, MONTEREY, CALIFORNIA; Asad A. Abidi, *CMOS Wireless Transceivers: The New Wave*, IEEE COMMUNICATIONS MAG., Aug. 1999, at 119; Jan Crols & Michael S. J. Steyaert, 45 IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS – II: ANALOG AND DIGITAL SIGNAL PROCESSING 269 (1998); and Jacques C. Rudell *et al.*, *A 1.9-GHz Wide-Band IF Double Conversion CMOS Receiver for Cordless Telephone Applications*, 32 IEEE J. OF SOLID-STATE CIRCUITS 2071 (1997), all incorporated by reference here in their entireties.

The integration of transceiver circuits is not a trivial problem, as it must take into account the requirements of the transceiver's circuitry and the communication standards governing the

transceiver's operation. From the perspective of the transceiver's circuitry, RF transceivers typically include sensitive components susceptible to noise and interference with one another and with external sources. Integrating the transceiver's circuitry into one integrated circuit would exacerbate interference among the various blocks of the transceiver's circuitry. Moreover, communication standards governing RF transceiver operation outline a set of requirements for noise, inter-modulation, blocking performance, output power, and spectral emission of the transceiver. Unfortunately, no method for addressing all of the above issues in high-performance RF receivers or transceivers, for example, RF transceivers used in cellular and telephony applications, has been developed. A need therefore exists for techniques of partitioning and integrating RF receivers or transceivers that would provide low-cost, low form-factor RF transceivers for high-performance applications, for example, in cellular handsets.

## Summary of the Invention

This invention provides interfacing techniques in radio-frequency (RF) apparatus, for example, receivers or transceivers. In one embodiment, an RF apparatus according to the invention includes receiver analog circuitry configured to produce a at least one digital receive signal from an analog radio-frequency signal. The receiver analog circuitry has a plurality of signal lines that are configurable by a control signal. The RF apparatus also has a receiver digital circuitry configured to accept the at least one digital receive signal from the receiver analog circuitry. The receiver digital circuitry has a plurality of signal lines that couple to the signal lines of the analog receiver circuitry. The signal lines of the digital receiver circuitry are also configurable by the control signal.

In another embodiment, a radio-frequency (RF) transceiver according to the invention includes a first integrated-circuit device that includes receiver analog circuitry configured to produce a at least one digital receive signal from an analog radio-frequency signal. The receiver analog circuitry has a plurality of signal lines that are configurable by a control signal. The RF transceiver also has a second integrated-circuit device that includes receiver digital circuitry configured to accept the at least one digital receive signal from the receiver analog circuitry. The receiver digital circuitry has a plurality of signal lines that couple to the signal lines of the receiver analog circuitry. The signal lines of the receiver digital circuitry are also configurable by the control signal.

Another aspect of the invention relates to methods of interfacing receiver digital circuitry and receiver analog circuitry within a radio-frequency (RF) apparatus, for example, a receiver or RF transceiver. In one embodiment, a method according to the invention includes providing receiver analog circuitry that has a plurality of signal lines that are configurable by a control signal. The method utilizes the receiver analog circuitry to produce at least one digital receive signal from an analog radio-frequency signal. The method also includes providing receiver digital circuitry that has a plurality of signal lines that are configurable by the control signal, and couple to the signal lines of the receiver analog circuitry. The method further includes accepting in the receiver digital circuitry the at least one digital receive signal from the receiver analog circuitry.

In another embodiment, a method according to the invention for interfacing receiver digital circuitry and receiver analog circuitry within an RF transceiver includes providing in a first integrated-circuit device a receiver analog circuitry that has a plurality of signal lines that are configurable by a control signal. The method further includes utilizing the receiver analog circuitry to produce at least one digital receive signal from an analog radio-frequency signal. The method provides in a second integrated-circuit device a receiver digital circuitry that has a plurality of signal lines that are configurable by the control signal and are coupled to the signal lines of the receiver analog circuitry. Finally, the method includes accepting in the receiver digital circuitry the at least one digital receive signal from the receiver analog circuitry.

## Description of the Drawings

The appended drawings illustrate only exemplary embodiments of the invention and therefore do not limit its scope. The disclosed inventive concepts lend themselves to other equally effective embodiments. In the drawings, the same numerals used in more than one drawing denote the same, similar, or equivalent functionality, components, or blocks.

FIG. 1 illustrates the block diagram of an RF transceiver. The RF transceiver includes radio circuitry that operations in conjunction with baseband processor circuitry.

FIG. 2A shows RF transceiver circuitry partitioned according to the invention.

FIG. 2B depicts another embodiment of RF transceiver circuitry partitioned according to the invention. In this embodiment, the reference generator resides within the same circuit partition, or circuit block, as does the receiver digital circuitry.

FIG. 2C illustrates yet another embodiment of RF transceiver circuitry partitioned according to invention. In this embodiment, the reference generator circuitry resides within the baseband processor circuitry.

FIG. 2D shows another embodiment of RF transceiver circuitry partitioned according to the invention. In this embodiment, the receiver digital circuitry resides within the baseband processor circuitry.